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COLD STORAGE OF FLORIDA GRAPEFRUIT[1]

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The steadily increasing production of grapefruit in Florida, which rose from 3,200,000 boxes in 1918–19 to 8,000,000 boxes in 1923–24, tends to furnish the market with more of this fruit than can readily be absorbed during its regular season. Occasional periods of oversupply, in which the fruit does not sell for enough to pay the cost of marketing, have occurred all too frequently in the last few years.

In an attempt to lengthen the season for the distribution and consumption of grapefruit, investigations on the storage of this fruit were begun in 1917. In the experimental work[2] it was found that cold storage improved the flavor of the fruit, that the bitter principle was broken down and the acid content decreased, while the sugar content remained about the same. Fruit in cold storage, however, had a tendency to pit; that is, to become covered with sunken brown spots after being held six weeks to two months, and it was necessary to work out some method to prevent this pitting in order to make cold storage commercially practicable. The method found to control this pitting was to cure the fruit by exposing it to a temperature of 65° to 80° F. with a relative humidity from 55 to 65 per cent for one to two weeks. Grapefruit cured in this way has been held three to six months without developing sufficient pitting to injure its commercial value.

[1] The writers wish to thank the Florida Citrus Exchange for its hearty cooperation in this work. The fruit for these experiments was supplied by that organization.

[2] Hawkins, L. A., and Magness, J. R. Some changes in Florida grapefruit in storage. *In* Jour. Agr. Research, vol. 20, pp. 357–373. 1920.

Hawkins, L. A. A physiological study of grapefruit ripening and storage. *In* Jour. Agr. Research, vol. 22, pp. 263–279, illus. 1921.

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Heretofore the experiments have been confined to quantities of grapefruit contained in not more than 10 or 15 boxes. It remained, therefore, to test the process in a commercial way with carload lots, storing the fruit and selling it on the market. This work was begun in the spring of 1922, and the present bulletin gives the results obtained from the curing and storing of about three carloads of grapefruit. A method of treating the fruit to control decay in storage is also discussed in connection with other experimental work.

EXPERIMENTAL WORK

The grapefruit used in all this experimental work was of different varieties, including Duncan, Silver Cluster, Walters, and seedlings, all of which contained seeds. The Marsh seedless variety was not used, because in previous work it was found that it had a tendency to develop an unattractive flavor if stored for a considerable period.

FIRST EXPERIMENT

In the first experiment 343 field crates of grapefruit picked March 27 and 28, 1922, were used. During the curing process, which lasted 13 days, the boxes were stacked four high in rows 1 foot apart on the packing-house floor, the temperature of the house varying from 67° to 85° F., with a rather wide range of humidity, 38 to 98 per cent. The mean temperature was about 75° F. and the average humidity about 65 per cent. The shrinkage of the fruit in this time, determined by the weight of samples at the beginning and end of the curing period, was found to be 3.9 per cent. Sixty boxes were inspected for decay when the fruit was packed. It was found that the average decay due to blue mold was 1.8 per cent and to stem-end rot 1.1 per cent, a total of 2.9 per cent during the 13 days. The 343 standard field crates packed out 231 boxes of merchantable fruit. This fruit was precooled, loaded in a refrigerator car, shipped under initial icing to the experimental cold-storage plant at the Arlington Experiment Farm, Va., and placed in 32° F. storage immediately on arrival April 17, about 20 days after harvesting.

The first lot of 100 boxes was sold June 2 to 6, after having been held 46 to 50 days. There was practically no pitting of the fruit. There was, however, 9.6 per cent decay in the first-grade fruit, 5 per cent in the second, and 13.7 in the third, necessitating sorting out the decayed fruit and repacking. A second lot was sold June 17, two months after the fruit was placed in storage, and, as in the first lot, there was practically no pitting. There was, however, 14 per cent decay in the first grade, 5.5 per cent in the second, and 14 per cent in the third. Small lots of second-grade fruit were sold on June 23 to 26, and there was an average of 9.9 per cent decay, with no appreciable pitting. The last lot of fruit, sold August 6 and 7, about three and two-thirds months from the time the fruit was placed in storage, or a little over four months from the time the fruit was harvested, showed considerable pitting. There was an average of 37.5 per cent decay in the first-grade fruit, 36 per cent in the second, and 44 per cent in the third. Although this fruit was edible and in good condition when removed from storage, it broke down very quickly at the ordinary market temperatures;

hence there was much waste. A few fruits held until September were in good condition for use immediately after removal from storage but would not stand up long at ordinary market temperatures. The prices received for the fruit were fairly high, being about $6.50 per box as compared with $3 to $3.50 when the fruit was placed in storage.

From this experiment it is evident that grapefruit packed at the beginning of April can be held for two months and be in fair condition when removed from storage, but it is necessary to sort it and remove the decayed fruit in order to obtain a good merchantable package. The increase in price after two months' storage in this case much more than paid the cost of storage and conditioning. Holding the fruit longer than two months, however, was hardly practicable, in view of the fact that there was considerable increase in decay over the longer period and the fruit broke down quickly when placed on the market. Cold storage, of course, only slows down the life processes, and fruit which is ripe or overripe on the trees can not be maintained indefinitely in good condition in storage.

SECOND EXPERIMENT

The second car of grapefruit for these storage experiments was packed January 15, 1923, and arrived in Washington January 25. This fruit was divided into five lots. Some of it was allowed to cure by standing in the packing house, whereas that in other lots was exposed to the fumes of the incomplete combustion of kerosene in a coloring room. The lots were as follows:

Lot 1. Picked January 8; treated with kerosene-stove gas 24 hours; then cured in packing-house air one week; shrinkage in weight before packing, 1.5 per cent.

Lot 2. Picked January 8; cured seven days in packing-house air; shrinkage in weight before packing, 1.5 per cent.

Lot 3. Picked January 10; treated with kerosene-stove gas 63 hours; shrinkage in weight before packing, 2.5 per cent.

Lot 4. Picked January 12; treated with kerosene-stove gas 48 hours; shrinkage in weight before packing, 2.5 per cent.

Lot 5. Control. Picked January 15 and packed the same day without curing.

The fruit was shipped in a refrigerator car under standard ventilation, arrived in good condition at the Arlington Experiment Farm January 23, and was unloaded January 24. No decay was found in any of the boxes inspected at the time the fruit was placed in storage. The temperature was 32° F., as in the first experiment. Five weeks after the fruit was placed in storage, when 200 boxes were sold, there was practically no decay in the first-grade fruit, 0.92 per cent in the second, and 0.47 per cent in the third. The fruit cured by treating with kerosene-stove gas showed the least pitting, about 4 per cent of which was noticeable from the standpoint of marketability; that is, the pits were more than one-eighth of an inch in diameter and fairly numerous. There was about 6 per cent pitting of this type in lot 2, which was cured in the packing house and was not treated with gas. On March 14, a little over seven weeks after the fruit was placed in storage and about nine weeks after the first lots were picked, the remainder was sold. There was less than 1 per cent decay in any of the lots. There was, however, some pitting.

Lot 1. Treated with kerosene-stove gas for 24 hours; had about 8 per cent pitting which could be considered noticeable from a commercial standpoint.

Lot 2. About 3 per cent rot in this lot, which was cured seven days at packing-house temperatures and showed some pitting.

Lot 3. Cured with kerosene-stove gas for 63 hours; showed 2.2 per cent pitting.

Lot 4. Cured 48 hours in kerosene-stove gas; showed 4 per cent pitting.

Lot 5. Picked and packed directly without curing; showed 5 per cent pitting.

This experiment indicates that about as good results can be obtained by curing by means of gas from the incomplete combustion of kerosene in an ordinary cooking stove as by allowing the fruit to stand at packing-house atmosphere from a week to 10 days and that fruit picked the early part of the season can be readily stored for six weeks to two months at 32° F. provided it is in good condition when placed in storage.

THIRD EXPERIMENT

A third car of grapefruit was stored in April, 1923. This fruit was picked April 10, immediately after which it was stacked in the packing house with air spaces between the stacks to provide good ventilation. During the day the fruit was exposed to the packing-house air, and at night when the humidity was high a large tent was placed over it, with a two-burner kerosene stove under the tent. The fruit was cured four days, during which time the humidity ranged from 47 to 73 per cent and the temperature from 79° to 84° F. The loss in weight was 1.6 per cent. The fruit was packed April 14, loaded and shipped under standard ventilation April 16, and arrived at the cold-storage plant at Arlington Experiment Farm, Va., April 23. An inspection on arrival showed 4 to 5 per cent decay. The fruit was unloaded immediately and placed in storage at a temperature of 32° F.

Examination after the fruit had been in storage six weeks showed 1.14 per cent decay due to stem-end rot and 3.2 per cent due to blue mold, making a total of 4.3 per cent in the first grade. The second grade showed 0.68 per cent stem-end rot and 3.3 per cent blue mold, totaling 3.98 per cent. In the third grade there was 0.85 per cent decay due to stem-end rot and 7.3 per cent due to blue mold, a total of 8.15 per cent. Another inspection one week later showed 3.39 per cent total decay in the first grade, 2.98 per cent in the second, and 14.3 per cent in the third. In the inspection after seven weeks' storage the first and second grades showed 4.4 per cent bad pitting; that is, pitting in which the sunken areas were more than one-eighth of an inch in diameter. The third grade showed 10.5 per cent of this type of pitting. Uncured fruit of the first grade showed 4.8 per cent bad pitting at this inspection. In seven weeks' storage, or about nine weeks from the tree, there was about the same amount of bad pitting in the uncured control as in the cured fruit, which is in accordance with the results obtained in the two other experiments, namely, that in a storage period of a month to six weeks at 32° F. the development of pitting even in uncured fruit is not liable to be of any appreciable significance in a commercial way.

It had been observed in earlier experiments that fruit which had been exposed to kerosene-stove gas for a sufficient length of time to loosen the stem buttons so that they were removed in passing

through the washer and polisher was less liable to decay than fruit which retained the buttons. This seemed to offer a method for controlling this disease in storage. It was tested experimentally with comparable fruit, from certain lots of which the buttons had been removed by treatment with stove gas, whereas others treated with gas for the same length of time still retained the buttons. The results of these experiments are shown in Table 1. Some of the fruit included in this table was held at a temperature of 70° F. throughout the experiment, while part of it was placed in cold storage at 32° for 30 days and then removed to a 70° temperature for varying lengths of time.

TABLE 1.—*Effect of removing buttons on the rot of grapefruit in storage*

Lot	Number of fruits	Buttons in or out	Number of days at—		Percentage of—		
			32° F.	70° F.	Stem-end rot	Blue mold	Sound fruit
No. 1	66	In		15	6.1	3.0	90.9
				33	24.2	3.0	72.8
				43	28.8	3.0	68.2
No. 2	84	Out		15	4.8	4.8	90.4
				33	14.3	4.8	80.9
				43	17.9	6.0	76.1
No. 3	43	In	30	11	34.9	0	65.1
			30	19	62.8	0	37.2
No. 4	13	Out	30	11	11.6	0	88.4
			30	19	16.3	0	83.7

It is evident from Table 1 that there is considerably less decay in the fruit from which the buttons have been removed. This was particularly true where the fruit had been in cold storage for one month. From this work and from other experiments along the same lines it seems probable that the removal of the buttons from the fruit by a treatment with stove gas would be of considerable benefit in the storage of grapefruit. Winston, Fulton, and Bowman[3] discuss this method of the control of stem-end rot in a recent publication.

In the course of this storage work examinations were made of a number of cars of fruit in various commercial storage plants, most of which was stored without curing. In two cars which had been stored three weeks and one month, respectively, there was no pitting. In an inspection of fruit from a third car stored eight weeks 48 per cent pitting was found in the second-grade fruit and 28 per cent in that of the first grade, while practically the same conditions were found in a fourth car that had been in storage for a little less than eight weeks.

GENERAL DISCUSSION

The results of these experiments, together with data presented in previous publications, indicate that the cold storage of grapefruit is practicable from a commercial standpoint. It is evident that storage in the latter part of the season may result in sufficient decay

[3] WINSTON, J. R., FULTON, H. R., and BOWMAN, J. J. Commercial control of citrus stem-end rot. U. S. Dept. Agr. Circ. 293, 10 pp., illus. 1923.

to make it necessary to sort and repack the fruit, thus increasing the cost of storing, and this, together with the storage charges, will undoubtedly warrant a somewhat higher price for this fruit than the usual market price at the height of the season. For a four to six weeks' storage period it is possible that curing the fruit before placing it in storage is unnecessary, as in most of our experiments the uncured lots did not begin to pit when stored at 32° F. until they had been in storage about six weeks, and in most cases the pitting was not sufficiently developed to make the appearance of the fruit objectionable from a commercial point of view until after two months' storage at this temperature.

The evidence indicates that fruit to be stored more than six weeks should be cured before being placed in storage if pitting is to be avoided. Curing can be accomplished either by exposing the fruit to air at a temperature around 70° to 75° F. with a humidity of about 65 per cent from one to two weeks or by treating it with kerosene-stove gas in a coloring room for three or four days. The latter method is preferable, because during the curing process the buttons will be loosened, so that most of them can be removed during the process of washing and brushing the fruit. The removal of the buttons will tend to decrease the decay in storage.

Fruit for late storage should be picked in March or the early part of April and not left on the tree too long. If the fruit is seeded it should be placed in storage before the seeds begin to sprout. Fruit that remains on the tree too long is liable to break down in storage or soon after it is removed and placed on the market. It should not be stored too long, as considerable deterioration will result both in storage and after it is marketed. Uncured fruit should not be stored more than six weeks to two months, but cured fruit can safely remain in storage from two to three months without danger of much pitting. It is possible that some curing might result by shipping the fruit to storage in ventilated cars rather than under refrigeration. In the warm spring weather, however, considerable decay may develop in fruit so shipped, and the loss from this cause may exceed the cost of refrigeration. Undoubtedly from a commercial standpoint the storage of grapefruit is practicable.

There is a limited demand for this fruit in competition with cantaloupes, strawberries, peaches, and other similar fruits, so that care should be taken that the market be not oversupplied. The placing of too much of a commodity in storage, especially of a fruit which has a limited storage period, such as grapefruit, may result in attempts to market more than can be absorbed in the limited time the fruit can be held in good condition. With careful attention to marketing conditions, however, there seems to be no reason why the storage of grapefruit in limited quantities should not be profitable and safe.

It must be remembered that grapefruit grown in Florida was used in these experiments, and these recommendations for curing and storing apply only to fruit from that State.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

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